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Savannah River Site
Sludge Characterization Model Using Dial-Up Factors

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Summary of Changes

Date	Rev	Description/Affected Sections	Reason
3/28/06	0	Initial creation of document	NA

ACRONYMS

DWPF	Defense Waste Processing Facility
ESP	Extended Sludge Processing
HAW	High Activity Waste
HHW	High Heat Waste
HM	H Modified
LAW	Low Activity Waste
LHW	Low Heat Waste
P	Purex
SRS	Savannah River Site
WCS	Waste Characterization System

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Electronic Attachments *(Filed with the electronic version of the document for historical use)*

<u>Excel® Workbooks:</u>

DWPF Sludge Material Estimate Workbook_3_28_06_HIGH
DWPF Sludge Material Estimate Workbook_3_28_06_LOW
DWPF Sludge Material Estimate Workbook_3_28_06_REC
DWPF Sludge Material Estimate Workbook_3_28_06_Original

1. INTRODUCTION AND SUMMARY OF RESULTS

The Waste Characterization System (WCS) [Hester, 1996] is an electronic information system used to support liquid waste management decisions. Currently, the system consists of two Excel® workbooks (WCS 1.5, Sludge 1.5) and a web based application that contains sample data (WCS II). While the system supports a wide variety of waste management operational decisions, the focus of this report is the prediction of sludge mass and composition contained in Sludge 1.5.

Sludge mass and composition are predicted based on a relatively sophisticated model developed in the early nineteen-nineties [Cavin, 1993] that estimated the mass of compounds disposed to the tanks using monthly production records from November 1954 through early 1993 as well as average compositions of various waste streams. Additions after 1993 are tracked separately and are not part of this analysis.

The main purpose of the model was to provide reasonable estimates on which to base the analysis of criticality issues in the Tank Farm. The results are also currently used for safety analysis, waste removal planning, tank closure planning, and Defense Waste Processing Facility (DWPF) sludge feed planning, among others.

The model contains a significant level of conservatism in the estimate of non-radioactive material mass, consistent with its use for criticality analysis; however, the level of conservatism used for assessing criticality issues has proven to be problematic when used as the basis for sludge removal and DWPF processing. The under prediction of sludge processed to date is 56% [Elder, 2006].

The purpose of this report is to document the results of the development and application of a modified approach to sludge mass predication.

'Dial-up' factors are developed using historical sample data based estimates of tank inventory compared to Sludge 1.5 based estimates. The ratio of these estimates is used as the basis for increasing the mass predictions to levels that are more consistent with those observed in the processing of DWPF sludge batches to date.

The application of 'dial-up' factors improves the prediction of sludge mass and composition, but is still not completely consistent with observed waste removal data. However, the results can be used to more effectively plan future sludge batches.

The total amount of sludge modeled as received in the tanks increased as shown in Table 1. (See Section 6.1 for the applicable electronic file references)

Table 1. Estimate of Sludge Mass Received in Waste Tanks (Kg) Using Different Dial-Up Factors

Compound	Original Model	Low Dial-Up Factors	Moderate (Recommended) Dial-Up Factors	High Dial-Up Factors
Al (OH)3	920,596	1,392,381	1,640,334	2,040,264
Fe (OH)3	1,369,622	1,848,030	1,937,711	3,261,367
Ni(OH)2	69,243	69,243	69,243	69,243
MnO2	160,697	146,918	276,131	330,910
UO2OH2	293,730	293,730	293,730	293,730
Other	812,786	1,088,430	1,118,938	1,653,256
Total	**3,626,674**	**4,839,732**	**5,336,087**	**7,649,256**

2. INVESTIGATION OF SLUDGE MASS PREDICTED VS. MEASURED

Now that four batches of sludge feed have been prepared for feed to DWPF, it is apparent that the total masses of sludge predicted using the current waste characterization model significantly underestimates the amount of sludge found in waste tanks during waste removal activities.

The discrepancy between the WCS model estimate and the sample based estimates was thoroughly investigated in 2005 and is documented in two reports. The first is a report characterizing the first four batches of feed to the DWPF using the available characterization data and Tank Farm information [Hamm, 2006b]. The second compares the amount of sludge solids (as calcine) actually removed from the tanks to the amount predicted using the current waste characterization model [Elder, 2006]. A summary of the results of the mass discrepancy investigation is found in Table 2.

The relationship between the four batches is shown in Figure 1. Note that the sludge removed from Tanks 17F and 18F is spread between sludge batches SB1A, SB1B, and SB2. The sludge from Tanks 1F, 2F, 3F, and 7F was sent to sludge batch SB3. The fifth sludge batch, SB4, is currently being prepared, and is composed mainly of sludge from Tank 11H.

Table 2. DWPF Sludge Feed Batch Mass – WCS Model Prediction vs. Measured (Kg) [Elder, 2006]

Sludge Batch	Calcined Solids Based on sample results	Calcined Solids Based on model	Percentage of Sample Estimate
SB1A (Tank 51)	315,000	173,000	55%
SB1B (Tank 51)	319,000	144,000	45%
SB2 (Tank 40)	417,000	270,000	65%
SB3 (Tank 40)	391,000	249,000	64%
SB4 (Tank 51)	281,000	121,000	43%
Combined	1,723,000	957,000	56%

The WCS model provides an estimate of discards to waste for amounts of four compounds - ($Fe(OH)_3$, $NaAlO_2$, MnO_2, and NiOH). Gravimetric factors are used to convert these to an elemental basis for Aluminum (Al), Iron (Fe), Manganese (Mn), and Nickel (Ni). The quantity of each of these elements predicted from the WCS model is compared to the amount estimated from DWPF sludge batch samples [Hamm, 2006b]. Note that although the total mass was consistently low on a calcine basis (Table 2), the mass of individual elements was consistently low for the combined batch (SB1A, SB1B, SB2) and the preliminary SB4. In SB3, the masses were slightly overestimated by the model (Table 3). (See Section 6.3 for the applicable electronic file references).

Figure 1. DWPF Sludge Batch Relationships

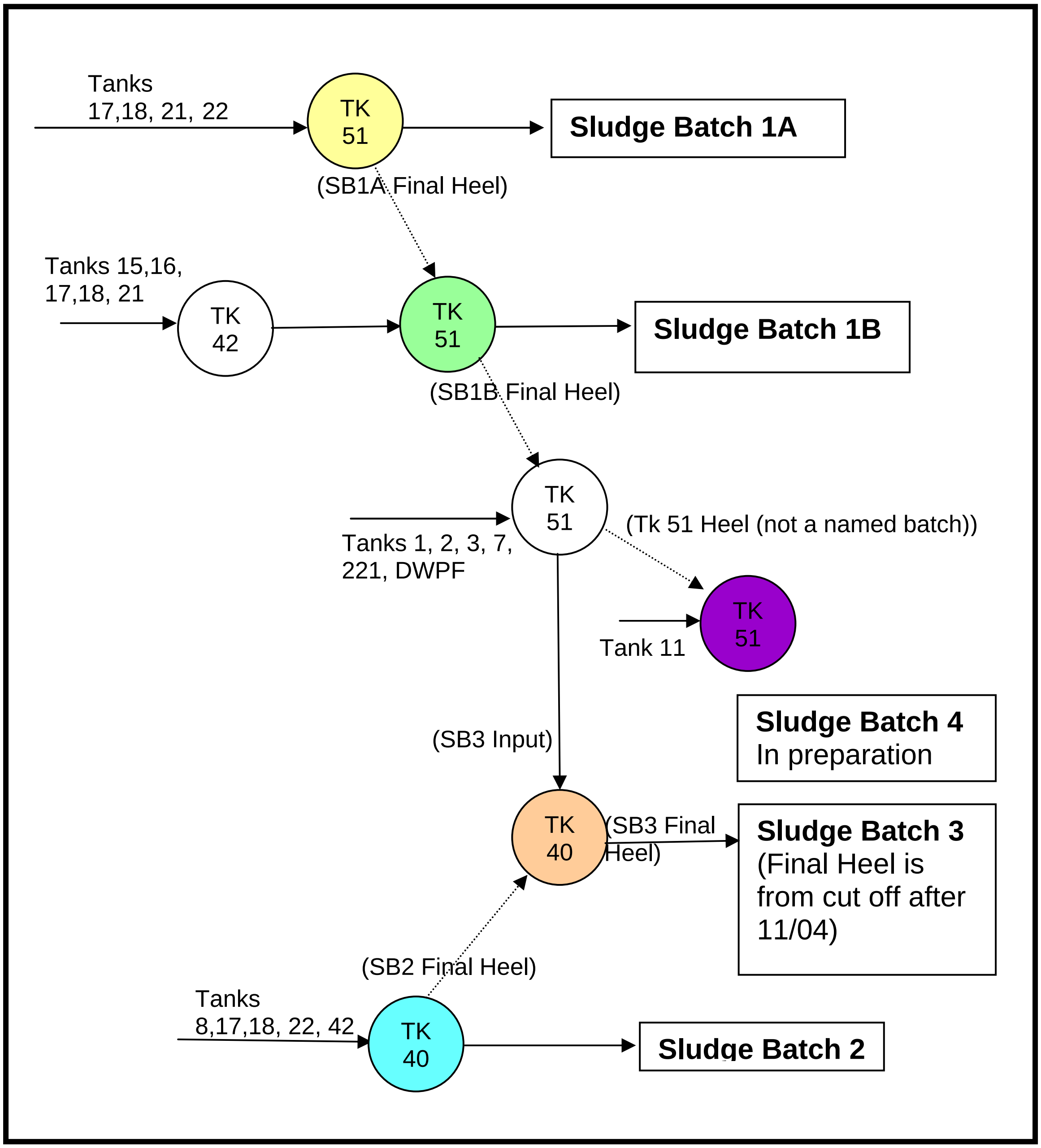

Table 3. Mass Input Comparison – WCS vs. Sample Data (from Attachment C)

Mass Input (kg) to Combined Batches (SB1A, SB1B, SB2)

Estimate Basis	Al	Fe	Mn	Ni
WCS Original Model	57,409	190,440	11,614	4,190
Sludge Batch Samples	89,642	310,243	41,705	8,876

Mass Input (kg) to Sludge Batch 3 (SB3)

Estimate Basis	Al	Fe	Mn	Ni
WCS Original Model	32,520	95,416	19,901	4,348
Sludge Batch Samples	25,248	67,900	19,404	4,618

Mass Input (kg) to Sludge Batch 4 (SB4)

Estimate Basis	Al	Fe	Mn	Ni
WCS Original Model	18,666	19,715	3,147	503
Sludge Batch Samples	70,381	34,956	8,325	2,593

3. MODEL IMPROVEMENTS CONSIDERED

As discussed in the Introduction, the discrepancy between the actual and predicted inventories prompted consideration of methods that could be used to improve the model to make it more useful for sludge planning.

Three possible approaches were developed. The first consisted of increasing the mass estimate of the early batches of sludge removed from the tanks based on actual waste removal information. This actually improved the model prediction considerably [Elder, 2006] for the first three batches; however, it does not provide a correction for future batches.

The second approach is to develop general ‘dial-up’ factors to be used to increase the estimates of waste sent to the tanks. The factors would be based on the ratio of historical sample based estimates of waste tank composition to the current model values. The ‘dial-up’ factor would be applied for all of the estimates for a given waste stream. Once these ratios were employed, the success of the factors would be determined by how well the improved model predicted the sludge batches formed to date. The factor would be adjusted, if needed, to provide a reasonable fit. The strength of this method is that it can be implemented with currently available information. The weakness is that variations over time in the waste streams can not be easily accommodated.

The third approach is to re-do the month-by-month, waste stream-by-waste stream estimates used to create the modeled composition using production factors modified by historical sludge sample and current waste removal data. This approach allows adjustments over time for each waste stream. A process would have to be developed for the basis for the corrections. Data from the processing of new sludge batches will greatly improve the quantity and quality of baseline information. This approach should be considered if the estimates need to be further refined.

The focus of this report is to document the results of the development and application of the second approach. The application of 'dial-up' factors improve the prediction of sludge mass and composition, but are still not completely consistent with observed waste removal data. The results can be extremely useful for planning purposes, but the user should keep in mind that they are predictions and are not actual measurements of tank contents.

4. ORIGINAL WCS MODEL (SLUDGE 1.5)

Sludge 1.5 was created using models based on known or estimated levels of production for each month [Cavin, 1993, 1994a, 1994b] for each waste stream. The information was used to model individual waste tank sludge inventories as documented in Chandler, 1994. Discussion of the original model follows.

4.1 Waste Streams

Monthly estimates of waste to the Tank Farm were developed for four reference waste streams because they represent the majority of SRS waste. The terms used to describe these streams merit discussion.

High Activity Waste (HAW) is that portion of the waste that contains the majority of the fission products. It is defined by where it comes from in the separations process. Multiple locations of waste from the process feed into the HAW stream. All of the HAW was sent to the Tank Farms through the High Heat Waste (HHW) header.

The Low Activity Waste (LAW) is also a combination of waste from various points in the separations process. Low Activity Waste is generally sent to the Tank Farm through the Low Heat Waste (LHW) header.

Purex process wastes from one of the LAW streams, specifically the LAW neutralization tank, were sent to the waste tanks via the HHW header from November 1954 to May 1961. After this time, the waste from this part of the Purex process was directed to the LHW header.

Monthly estimates of waste to the Tank Farm were developed for each of these four reference waste streams (Purex LHW, Purex HHW, HM LHW, and HM HHW).

4.2 WCS Mass Estimation Method

An example of the method used to estimate waste discarded to the tanks is provided below. The example uses two different time periods to show how the change in production rate (measured in metric tons of uranium (MTU) and waste generation factors (measured in mass of compound per MTU)) effects the predicted mass.

The estimate of iron hydroxide $Fe(OH)_3$ generated in November 1954 was modeled based on the processing of 10 MTU and the waste generation factor of 7.9 kg $Fe(OH)_3$/MTU [Cavin, 1993]. This results in an estimate of 79 kg of $Fe(OH)_3$. This amount of waste was assigned to Tank 1 based on production records showing that all of the waste from this stream was sent to Tank 1 during this time period [Cavin, 1994a]. The combined information is summarized and provides the predictions documented in Chandler, 1994 which are then input into Sludge 1.5.

The model was adjusted as needed to account for changes in waste generation caused by flowsheet modifications or the processing of unusual materials. This approach was applied from November 1954 to early 1993, which is the time period when the majority of the waste sludge was generated and sent to the high-level waste tanks. The basis factors selected for the model are documented in Cavin, 1993 and are not repeated in this report.

The authors noted several reasons why the masses determined in this manner tend to be low. The amount of chemical added will be underestimated because it does not consider ‘off flowsheet’ addition and because the processes would often run at higher than flowsheet values.

Nickel and manganese entered the waste stream from several intermittent sources. The current model attempted to smooth out this effect by using constants to represent the accumulated additions from the varied sources. This will of necessity be inaccurate.

Aluminum partitions between the supernate and sludge phases and the amount that stays in the sludge varies and is dependent on factors such as waste stream composition, neutralization rate, temperature, and time, among others. Thus, the amount of aluminum that stays in the tank is not easily predicted. The current model uses a single, constant value for aluminum partition between phases. The amount of aluminum also changed over time based on the type of assemblies processed, however, this was not taken into account and a single value was used to model the aluminum contribution to the waste.

Since the main reason for assembling the monthly estimates was to evaluate criticality issues in the Tank Farm, the underestimate of the mass of non-radioactive compounds is conservative.

5. DIAL-UP FACTOR CONCEPT AND DEVELOPMENT

'Dial-up' factors are developed using historical sample data based estimates of tank inventory compared to Sludge 1.5 based estimates. For example, samples from Tank 15H indicate a composition of 8 wt% iron (Fe) in the washed, dried insoluble solids. Knowing that the sample was taken in 1978 from the bottom 36 inches of the sludge layer, and that the volume of the compacted sludge was estimated to be 323,000 gallons, the amount of Fe estimated to be in the tank was 29,341 kg. Note that in addition to the sample results, it was assumed that there was 1 liter of centrifuged sludge for each 2 liters of settled sludge. The Sludge 1.5 estimate for this tank as of the sampling time was 14,444 kg. The ratio of the two amounts (29,341/14,444) results in a 'dial-up' factor of 2. Note that this process can only be applied where sample data is available for relatively pure waste streams.

The concept of using 'dial-up' factors assumes that the underestimates are consistent for a specific waste stream. The 'dial-up' factor is applied regardless of the basis factor used.

For example, the basis factor for Purex HHW for $Fe(OH)_3$ for November 1954 was 7.9 kg/MTU as discussed above. In July of 1956, this basis factor was 4.4 kg $Fe(OH)_3$ per MTU. Since the production records show that 95 MTU were processed that month, the amount of $Fe(OH)_3$ sent to waste was 418 kg. When the same 'dial-up' factor is applied to both, the November 1954 value increases to 158 kg and the June 1956 value increases to 836 kg (Table 4).

Table 4. Sludge 1.5 Model Input Calculations

Month-Yr	Metric Tons Uranium Processed (MTU)	$Fe(OH)_3$ Basis Factor (kg/MTU)	Original $Fe(OH)_3$ Estimate (kg)	Dial-Up Factor	Dialed Up $Fe(OH)_3$ Estimate (kg)
Nov-54	10	7.9	79	2	158
July-56	95	4.4	418	2	836

Originally, the approach used was to develop a single 'dial-up' factor for each of the four compounds ($Fe(OH)_3$, $NaAlO_2$, MnO_2, NiOH) for each of the four reference waste streams (Purex LHW, Purex HHW, HM LHW, HM HHW). This approach was later modified to include separate factors for Purex wastes sent to the tanks before May of 1961. This date was chosen because it represents a significant change in the routing of the waste. Prior to this time, a significant portion of the Purex low-activity waste was included in the waste sent to the high-heat waste header. After May of 1961, all of the low-activity waste was sent to the low-heat waste header.

5.1 Historical Volumes of Sludge Used in Dial up Factor Estimates

Reasonable estimates of sludge volume are required in order to use historical sample data for tank content estimation. For the purposes of this work, sludge volume is determined from estimates of the height of settled sludge in the tank combined with a fill factor used to convert height to volume. The factor for the Type I tanks (Tank 1 thru 12) is 2710 gal/inch. The factor for the Type II tanks (Tank 13 thru 16) is 3500 gal/inch and for the Type IV tanks (Tanks 17 thru 24) is 3540 gal/inch. All of the rest of the tanks (Tanks 25 thru 51) are Type III/IIIA with a fill factor of 3510 gal/in.

The historical volume of sludge (generally highest level of well compacted sludge) is recorded in Table 5. These do not correspond to the current level of sludge in the tank if the tank has undergone waste removal.

The historical values are used in combination with sample data in order to provide an estimate of the amount of each of the modeled compounds originally deposited into each tank.

Table 5. Historical Settled Sludge Volumes (Gallons)

Tank	Original Settled Sludge	Reference
1F	41,000	McNatt, 1978
2F	49,000	SRS, 1966
3F	78,000	SRS, 1968
4F	127,000	Davis, 1982
5F	41,000	Davis, 1982
6F	25,000	Davis, 1982
7F	221,000	Davis, 1982
8F	287,000	Davis, 1982
9H	46,000	Fowler, 1980
10H	67,000	Fowler, 1980
11H	225,000	Davis, 1982
12H	257,000	Davis, 1982
13H	252,000	Davis, 1982
14H	125,000	Davis, 1982
15H	323,000	Davis, 1982
16H	77,000	Hamm, 2006a
17F	378,000	Davis, 1982
18F	551,000	Davis, 1982

5.2 Reference Sludge Composition Used in Dial Up Factor Estimates

The reference composition of the sludge from the four waste streams was developed in the early nineteen-eighties and summarized by Hester in 1996 and is shown in the following table:

Table 6. Reference Composition by Compound (Wt% Washed, Dried Insoluble Solids)

Species	Purex LHW	Purex HHW	HM LHW	HM HHW
$Al(OH)_3$	13.9	6.5	20.6	67.0
$Fe(OH)_3$	48	48.5	46	10.2
MnO_2	4.2	12.1	11.8	2.6
$Ni(OH)_2$	3.4	5.8	0.7	1.0

Applying the appropriate gravimetric factors, the composition can be expressed in terms of weight percent of each significant element. This corresponds to the following:

Table 7. Reference Composition by Element (Wt% Washed, Dried Insoluble Solids)

Species	Purex LHW	Purex HHW	HM LHW	HM HHW
Al	4.6	2.1	6.8	22.1
Fe	25.1	25.4	24	5.3
Mn	2.7	7.7	4.5	1.6
Ni	2.2	3.7	0.4	0.6

‘Dial-up’ factors were calculated for each waste stream using the reference compositions and historical sludge volume information ratioed to information taken from the Sludge 1.5 model. ‘Dial-up’ factors using the reference composition are included in Attachment A.

5.3 Tank Specific Composition and Volume Information Used in Dial-Up Factor Estimates

The following provides details on the sample results and sludge volume estimates that were used in the estimation of ‘dial-up’ factors. Sludge volume information comes from Table, above. All of the sample results discussed in the following is summarized in Attachment A. Sample Data Used for Dial-Up Factor Estimates.

Tank 1F

Tank 1F received pre-May 1961 Purex HHW, post-May 1961 LHW, and post-May 1961 Purex HHW. No sample data has been found for the tank. It was estimated to contain about 41,000 gallons of settled sludge [McNatt, 1978], with 34,000 gallons transferred to Tank 7F in 1969. Most of this sludge has now been incorporated into Sludge Batch 3. Only a small amount remains, and it is estimated at about 7,000 gallons. The tank was used as a salt receiver and has a substantial volume of salt at this time. 'Dial-up' factors were not developed for this tank since it contains a mixture of waste types.

Tank 2F

Tank 2F received only pre-May 1961 Purex HHW. The tank contained about 18 inches of settled sludge prior to waste removal [SRS, 1966]. This corresponds to about 49,000 gallons. Approximately 45,000 gallons was transferred to Tank 7F and is now in Sludge Batch 3. Only a small volume of sludge remains, it has been estimated at about 4,000 gallons (1.5 inches). The tank was used as a salt receiver and has a substantial volume of salt at this time.

Tank 2F sample results were 2.2 wt% Al, 17.3 wt% Fe, 17.3 wt% Mn, and 0.5 wt% Ni, all expressed as wt% of washed, dried insoluble solids.

Tank 3F

Tank 3F has no sample data, but it should be very similar to Tank 2F. It received only pre-May 1961 Purex HHW. About 90 to 95% of the sludge was removed from the tank, [SRS, 1968]. The amount removed was estimated to be about 70,000 gallons. Assuming this was 90% of the original inventory, there were about 78,000 gallons of settled sludge in the tank prior to waste removal.

The sludge was sent to Tank 7F and is now mostly in Sludge Batch 3. The tank was used as a salt receiver and has a substantial volume of salt at this time.

Since Tank 2F and Tank 3F received the same type of waste, Tank 2F sample results will be used to represent Tank 3F composition. Sample results were 2.2 wt% Al, 17.3 wt% Fe, 17.3 wt% Mn, and 0.5 wt% Ni, all expressed as wt% of washed, dried insoluble solids.

Tank 4F

Tank 4F contains Purex HHW from post May-1961. Waste removal has never been performed on this tank and it is estimated to contain about 127,000 gallons of settled sludge [Davis, 1982].

The tank was sampled in September of 1975 [Stone, 1976] but sample results were only reported for a composite of sludge from Tanks 4F and 6F. Fowler reports results from one additional sample [Hamm, 2006a].

The Tank 4F/6F composite and the later Tank 4F sample will be used to represent both Tanks 4F and 6F. The results were similar so the maximum values were used. Sample results were 2.3 wt% Al, 33.6 wt% Fe, 2 wt% Mn, and 6.3 wt% Ni, all expressed as wt% of washed, dried insoluble solids.

Tank 5F

Tank 5F contains a mix of pre-1961 Purex HHW and post-1961 Purex HHW. The tank was sampled in 1974 and in 1975 [Stone1976a, 1976b]. However, the volume of pre-May 1961 sludge is small relative to post-1961 sludge and the samples were taken after the tank had received predominantly post-1961 Purex HHW. Therefore, the tank will be used to represent the post-1961 Purex HHW stream.

Based on an average sludge level of 15.1 inches determined in July of 1976 [Davis, 1982], there were about 41,000 gallons of settled sludge.

Two sets of sample data were considered for this study [Stone, 1976a, 1976b]. The results were similar and the maximum values for each element was used to represent the composition. The maximum sample values were 1.57 wt% Al, 28.9 wt% Fe, 10.8 wt% Mn, and 6.34 wt% Ni, all expressed as weight percent of washed, dried insoluble solids.

Tank 6F

Tank 6F contains only post May-1961 Purex HHW sludge and has never undergone sludge removal. The average sludge level was recorded as 9.2 inches in the 1980s [Davis 1982]. This is a volume of about 25,000 gallons.

As discussed above, the Tank 4F/6F composite and the later Tank 4F sample will be used to represent both Tanks 4F and 6F. The results were similar so the maximum values were used. sample results were 2.3 wt% Al, 33.6 wt% Fe, 2 wt% Mn, and 6.3 wt% Ni, all expressed as wt% of washed, dried insoluble solids.

Tank 7F

Tank 7F contained pre-1961 Purex LHW and received sludge from Tanks 1, 2, and 3 which was predominantly pre-1961 Purex HHW. It also contained some amount of sand and coal from reactor heat exchanger cleaning. Because of the mixed nature of the waste in the tank and the lack of good quality sample results, the tank was not included in the dial-up factor calculations.

The average sludge level was estimated at 81.5 inches [Davis, 1982] or 221,000 gallons.

Sludge removal was performed in 2002 and 2003. The amount of iron removed was estimated to be 156,000 lbs while the aluminum was about 1/3 as much, or about 52,000 lbs [Bumgardner, 2003].

About 3.25 inches of sludge (8,800 gallons) remained in the tank after sludge removal.

There was considerable uncertainty about the starting level of sludge, so the total volume of settled sludge removed is uncertain.

Tank 8F

Tank 8F contained a mix of Purex LHW and HHW. The sludge level was very uneven. It was recorded at about 105.9 in on the average (6/12/80 morning report), which is 287,000 gallons [Davis, 1982]. About 96% of the sludge was removed in 2001 and the remaining sludge was removed in 2004. Samples have been taken and analytical data is available, however, the tank does not contain a pure type of sludge so it has not been included in the dial up factor calculations.

Tank 9H

Tank 9H contained pre-May 1961 Purex HHW sludge. Most of the sludge from this tank was removed and sent to Tank 13H. The amount removed was estimated to be 42,000 gallons and the tank was estimated to have a residual of about 4,000 gallons [Fowler, 1980]. This makes the total initial inventory equal to 46,000 gallons of settled sludge. The tank was used as a salt receiver and has a substantial volume of salt at this time.

A sample was taken during waste removal and the values were 2.4 wt% Al, 14.6 wt% Fe, 9.6 wt% Mn, and 0.5 wt% Ni, all expressed as weight percent of washed, dried insoluble solids [Fowler, 1980]. A ratio of 2.4 gallons of settled to centrifuged sludge was measured. Since Tank 10H contains a similar type of waste, these results will also be used for that tank.

The maximums of the combined results were 3.5 wt% Al, 14.6 wt% Fe, 9.6 wt% Mn, and 1.7 wt% Ni.

Tank 10H

Tank 10H contains mostly pre-May 1961 Purex HHW sludge. It underwent sludge removal to Tank 13H in 1967. The volume removed was estimated to be 63,000 gallons with a residual volume of 4,000 gallons. This represents an original settled sludge volume of 67,000 gallons [Fowler, 1980].

A sample was taken during sludge removal in 1966 with results of Al at 3.5 wt% and Ni at 1.7 wt%. The Fe and Mn results were not used because they were 'less-than' values. Based on the similarity of the material, the sludge composition is based on the Tank 9H analysis - 2.4 wt% Al, 14.6 wt% Fe, 9.6 wt% Mn, and 0.5 wt% Ni.

As discussed above, the maximums of the combined results were 3.5 wt% Al, 14.6 wt% Fe, 9.6 wt% Mn, and 1.7 wt% Ni.

The tank was used as a salt receiver and has some salt at this time.

Tank 11H

Tank 11H contains a mix of waste types. It originally received Purex LHW and Neptunium Frame waste. It later received HM HAW waste. It underwent waste removal in 1969 when it was estimated to contain about 83 inches of sludge or 225,000 gallons. About 198,000 gallons were transferred to Tank 13H and about 10 inches (27,000 gallon) remained. In 2004 and 2005, some amount of Tank 11H sludge was transferred to Tank 51H to make up Sludge Batch 4. The sludge volume estimates are highly uncertain due to mounding of the sludge in the tank

Samples have been taken and results are available, however, they were not included in the dial up factor estimates because they do not represent a pure waste type.

Tank 12H

Tank 12H is mainly HM HHW, although it also received some thorium program waste. Sludge soundings of the tank in October of 1978 indicted 108 inches of sludge in riser 1, 121 inches in riser 5, and 89 inches in riser 8. The average sludge level was estimated at 94.8 inches [Davis, 1980]. The tank calibration factor is 2710 gallons/inch. Therefore, the amount of sludge in the tank was about 257,000 gallons. The tank has never undergone sludge removal.

The tank was sampled in September of 1975 with the 3-liter sampler, and in both August and September of 1984 with the 25-liter sampler. Thirteen sets of sample results were evaluated for use in the dial up factor estimates.

Aluminum ranged from 21.7 to 30.16 wt%, iron ranged from 2.5 to 4.49 wt%, manganese ranged from 1.55 to 1.86 wt%, and nickel ranged from 0.113 to 0.46 wt%.
All results are expressed as weight percent of washed, dried insoluble solids.

Dial up factors were evaluated at the ends of the ranges of values.

Tank 13H

Tank 13H contains mainly HM LHW originally deposited in the tank and also sludge from Tanks 9H, 10H, 14H, and 11H.

There was an estimate of 115 inches of settled sludge in 1974, but the tank was active up until that time so compaction of the settled sludge was incomplete. The current estimate of settled sludge is 72 inches or 252,000 gallons [Davis, 1982].

Samples were taken in August 1974 and July 1975. The results were significantly different, so the maximum values were used to evaluate dial-up factors. The maximum values were 9.22 wt% Al, 27.9 wt% Fe, 8.8 wt% Mn, and 0.5 wt% Ni, all expressed as weight percent of washed, dried insoluble solids.

Since the results were taken in 1974 and 1975 (after the additions from the other tanks), the results will not be pure for the waste stream. However, they were used in the dial up factor analysis because they were the only sample available for HM LHW.

Tank 14H

Tank 14H contains a mix of Purex and HM wastes. The volume was estimated to be about 125,000 gallons [Davis, 1982] About 98,000 gallons was removed to Tank 13H and about 27,000 gallons remain. Since the tank does not contain a pure waste type, it was not used in the analysis.

Tank 15H

Tank 15H received mainly HM HHW although it also received some Thorium program waste. Tank 15H contained about 105 inches of settled sludge (323,000 gallons) [Davis, 1982]. Five sets of results were evaluated for use in dial up factor estimates. The values selected were 20.5 wt% Al, 8 wt% Fe, 0.8 wt% Mn, and 0.77 wt% Ni, all expressed as weight percent of washed, dried insoluble solids.

Tank 16H

Tank 16H contained a mix of HM HHW and HM LHW. It underwent waste removal in 1978 and 1979. The volume in the tank was estimated at 77,000 gallons [Hamm, 2006a]. Since the tank did not contain a pure type of waste, the sample results were not used in the dial up factor analysis.

Tank 17F

Tank 17F contained a large amount of post May 1961 Purex LHW. In 1980, the settled sludge level was estimated to be 106.8 inches or 378,000 gallons [Davis, 1982]. The tank contents were slurried and transferred to Tank 18F.

The sludge was sampled in Tank 18F and this sample is used to represent the waste stream. The sludge composition was 6.3 wt% Al, 45.5 wt% Fe, 3.6 wt% Mn, and 0.6 wt% Ni, all expressed as weight percent of washed, dried insoluble solids.

Samples taken during waste removal indicate that there were about 1,052,860 kg insoluble solids removed [Hamm, 2006c]

Tank 18F

Tank 18F received a large amount of Purex LHW, followed by the Purex LHW removed from Tank 17F and then more Purex LHW. The final total was estimated to be 551,000 gallons [Davis, 1982].

The concentrations were taken from sample 18A and were 6.3 wt% Al, 45.5 wt% Fe, 3.6 wt% Mn, and 0.6 wt% Ni, all expressed as weight percent of washed, dried insoluble solids [Hamm, 2006a].

Most of the sludge from Tank 18F has been processed into glass in sludge batches 1A, 1B, and 2.

5.4 Dial-up Factor Calculation Assumptions

‘Dial-up’ factors were calculated from historical sludge data and from the reference compositions as discussed in the previous section. The individual ‘dial-up’ factors are shown in Attachment B. Dial-Up Factor Estimates.

All of the sludge data used for this report was collected when sludge compositions were reported as weight percent of washed, dried insoluble solids. This measurement is very useful when comparing sludges from different tanks with different levels of compaction and different levels of salt because it minimizes the impact of these variations.

In order to apply the sludge composition information to settled sludge, an estimate of the mass of insoluble solids in the tank has been made. In reality, there is not a single value that can be used to characterize the mass of dry, insoluble solids per volume of settled sludge. However, a value has been established in order to proceed.

Information from a variety of sources was considered. It is presented in different units depending on what the researcher was trying to accomplish. Early historical data has shown 0.25 to 0.3 kg/liter of centrifuged sludge and a range of 2 to 4 volumes of settled sludge per volume of centrifuged sludge [Kelley, 1973]. Laboratory values have been observed from 1.5 to 2.8 lbs dried insoluble solids/gallon settled sludge [Fowler, 1984]. WCS currently uses a value of 1.95 lbs of dried, insoluble solids per gallon of settled sludge [Hester, 1996]. Analysis of the data from Tank 17F waste removal efforts indicate 6.2 lbs of dried, insoluble solids/gallon of settled sludge [Hamm, 2006c].

Using this information as a guide, a value of 2 volumes of settled sludge/volume of centrifuged sludge and a value of 0.6 kg dried, insoluble solids/liter of centrifuged sludge was used for all of the ‘dial-up’ factor estimates.

5.5 “Dial-up Factors” for Case Studies

In order to show the effect of the dial up factors on the sludge mass estimates, three cases were run. Factors were selected from the low end of the range and the high end of the range for each waste stream. See Attachment B. Dial-Up Factor Estimates for the details. The values were put into the new model and the effect on the total mass of each element was calculated (by the model). The results were compared to those observed from the sample data. If the spread between the values was large, the factor was turned down until it was more in line with the sample data. The results of this trial-and-error process are a set of moderate ‘dial-up’ factors that are recommended for use for sludge removal and processing plans.

The electronic attachments to this report contain working spreadsheets that can be used to adjust the factors and examine the results. The applicable electronic files are as follows:

DWPF Sludge Material Estimate Workbook_3_28_06_Original,
DWPF Sludge Material Estimate Workbook_3_28_06_LOW,
DWPF Sludge Material Estimate Workbook_3_28_06_REC,
DWPF Sludge Material Estimate Workbook_3_28_06_HIGH,

See Tab INPUT CALCS – Do not Sort , Cells in the area from AL1895 through CO 1907 for the ‘dial-up’ factor input area and see Tab WCS vs. Sample Comparison, for the impact. The best place to monitor the effect is in the input to the batches. The combination of Sludge Batches 1A, 1B and 2 (Rows 68 and 69), Sludge Batch 2 (Rows 47 and 48), Sludge Batch 3 (Rows 63 and 64) and the preliminary Sludge Batch 4 (Rows 71 and 72).

Tables 8, 9, and 10 provide ‘dial-up’ factors for the low, moderate, and high case sludge mass estimates.

Table 8. Low Dial-Up Factors

Element	HM HHW	HM LHW	Pre -1961 Purex HHW	Pre -1961 Purex LHW	Post -1961 Purex HHW	Post -1961 Purex LHW
Fe	1.5	2	1.9	1	1.1	1
Al	2.0	2.3	3.1	1	0.3	1
Mn	0.4	n/a	0.8	2	0.4	2
Ni	n/a	n/a	n/a	n/a	n/a	n/a

N/A is not applicable

Table 9. Recommended (Moderate) Dial-Up Factors

Element	HM HHW	HM LHW	Pre -1961 Purex HHW	Pre -1961 Purex LHW	Post -1961 Purex HHW	Post -1961 Purex LHW
Fe	1.5	2	2	1	2	1
Al	2.5	2.5	3	1	1	1
Mn	1	n/a	2	2	2	2
Ni	n/a	n/a	n/a	n/a	n/a	n/a

N/A is not applicable

Table 10. High Dial-Up Factors

Element	HM HHW	HM LHW	Pre -1961 Purex HHW	Pre -1961 Purex LHW	Post -1961 Purex HHW	Post -1961 Purex LHW
Fe	1.6	5	2.7	1	1.8	1.6
Al	3.3	2.5	5.1	1	0.6	1.1
Mn	0.6	n/a	2.7	2	1.5	2.8
Ni	n/a	n/a	n/a	n/a	n/a	n/a

N/A is not applicable

6. RESULTS FOR DIAL-UP FACTOR CASE STUDIES

Once ‘dial-up’ factors were developed for each waste stream, they were used in a modified version of Sludge 1.5 to estimate the mass of each compound disposed to the waste tanks.

Note that the mass of many other compounds is estimated based on the $Fe(OH)_3$ for each month, therefore the total mass estimate for the tank is more than the sum of these four compounds.

The effect of varying the factors from the low to high is illustrated by three case studies.

6.1 Case Studies Results for Sludge Mass Estimate

Using the results from the case studies, the total amount of sludge modeled as received in the tanks increased as shown in the table below.

Table 11. Sludge Mass Received in Waste Tanks (Kg)

Compound	Original Model	Low Dial-Up Factors	Recommended Dial-Up Factors	High Dial-Up Factors
Al $(OH)_3$	920,596	1,392,381	1,640,334	2,040,264
Fe $(OH)_3$	1,369,622	1,848,030	1,937,711	3,261,367
$Ni(OH)_2$	69,243	69,243	69,243	69,243
MnO_2	160,697	146,918	276,131	330,910
$UO_2(OH)_2$	293,730	293,730	293,730	293,730
Other	812,786	1,089,430	1,118,938	1,653,742
Total	**3,626,674**	**4,839,732**	**5,336,087**	**7,649,256**

The applicable electronic files are as follows:

Workbook Name:
DWPF Sludge Material Estimate Workbook_3_28_06_Original,
DWPF Sludge Material Estimate Workbook_3_28_06_LOW,
DWPF Sludge Material Estimate Workbook_3_28_06_REC,
DWPF Sludge Material Estimate Workbook_3_28_06_HIGHl,

Tab and Cell Location:
Tab Pred Sludge (NEW)
Al(OH)3 in Cell BX58, Fe(OH)3 in cell CI58, Ni(OH)2 in cell CV58, MnO2 in cell CN58, UO2(OH)2 in cell DE58, Total in cell C58, Other is by difference

6.2 Individual Element Results Comparison to DWPF Sample Data

The level of success of the 'dial-up' factor method improvement to Sludge 1.5 can be determined by comparison of the estimated quantities of the elements from the DWPF samples. Only the moderate case (recommended) is shown in the following table (Table 14). The information is taken from Attachment C. Comparison of WCS Original Model to Sample Based Estimates and Attachment D. Dial-Up Mass at Recommended Values Compared to Sample Based Mass Estimates.

The applicable electronic files for these attachments are as follows:

Workbook Name:
DWPF Sludge Material Estimate Workbook_3_28_06_Original,
DWPF Sludge Material Estimate Workbook_3_28_06_REC,

Tab WCS vs. Sample Comparison, Combination of Sludge Batches 1A, 1B and 2 (Rows 68 and 69), Sludge Batch 2 (Rows 47 and 48), Sludge Batch 3 (Rows 63 and 64) and the preliminary Sludge Batch 4 (Rows 71 and 72).

The values for Al and Fe for the Sum of SB1A, SB1B, and SB2 batches shows that while the updated amounts are much closer to the sludge sample results, they are still somewhat short of the actuals. In the case of SB3, both the original and the dialed-up values over predict the amounts based on the sludge samples. Note that the SB3 batch characterization is complicated by the many transfers into and out of the tank and the time delays in sampling. See Attachment E for a discussion of the effect of different approaches to batch characterization. The values for Al for the preliminary SB4 are still short of the sludge sample results, but the values for Fe are very close.

These results show that the dial-up factor method provides an improved prediction of sludge mass but it is still not completely consistent with sample data.

Table 12. Sludge Mass Comparison – Original WCS Model, Moderate 'Dial-up' Factor Model, Sample Based Model (Attachments C and D)

Input Kg (Sum of SB1A, SB1B, and SB2)

	Al	Fe	Mn	Ni
Input Based on WCS Original Model	57, 409	190,440	11,614	4,190
Input Based on Moderate Dial Up Factors	78,387	232,517	21,394	4,190
Input Based on Sludge Batch Sample	89,642	310,243	41,705	8,876

Input (Sludge Batch 3)

	Al	Fe	Mn	Ni
Input Based on WCS Original	32,520	95,416	19,901	4,348
Input Based on	36,181	110,448	37,809	4,348

Moderate Dial Up Factors				
Input Based on Samples (Approach A)	25,248	67,900	19,404	4,618
Input Based on Samples (Approach B)	35,001	78,649	22,970	5,365

Input (Preliminary Sludge Batch 4)

	Al	Fe	Mn	Ni
Input Based on WCS Original	18,666	19,715	3,147	503
Input Based on Moderate Dial Up Factors	41,777	31,475	4,199	503
Input Based on Samples	70,381	34,956	8,325	2,593

7. UNCERTAINTY

All of the information in this report should be used with the understanding that the reported values are useful approximations of the inventories in the tanks. This information is useful for planning purposes. It is not possible to provide a perfect approximation. There is uncertainty in the sample results as well as in the estimates of the level of sludge in the tank.

8. RECOMMENDATIONS

There were several lessons learned in the preparation of this information. The dial-up factor approach can be used to estimate a more realistic amount of sludge to be processed into glass. It should be used as an aide to planning and the estimates generated should be used with a clear understanding of their limitations. It is not necessary to zero in on exactly the ‘right’ factors for planning purposes. The usefulness of the analysis is in showing the range of estimates of sludge inventory, not in pinning down a single total value of sludge. Nevertheless, this document has an electronic attachment which can be used to try out various dial-up factors and to determine the effect on the mass of sludge in the tanks.

The true value of the mass of sludge in the tanks will only be known after all of it has been processed. However, it is still possible to make reasonable plans for waste removal and processing based on the current level of information about sludge.

Characterization of sludge during waste removal and as a part of sludge batch qualification is critically important to improving the understanding of the entire sludge stream. Recommendations for a minimum, standardized characterization of sludge samples are provided in Hamm, 2006a as Attachment F.

A plan for characterizing the remaining settled sludge is being developed. The tanks which contain the largest volume of sludge still to be processed are shown in Table 13. Analyses from these tanks would generate the most benefit in terms of improving future mass estimates.

Table 13. Remaining Sludge Tanks with Large Amounts of Sludge

Tank	Volume Estimate (Gallons)	Waste Type
4F	127,000	P HHW
12H	257,000	HM HHW
13H	252,000	P HHW, HM, LHW
15H	198,000	HM HHW
26F	259,000	P LHW
33F	355,000	P LHW/HHW
34F	204,000	P HHW
39H	104,000	HM LHW/HHW
43H	232,000	HM LHW
47F	248,000	P LHW

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HARDCOPY ATTACHMENTS

A. Sample Data Used for Dial-Up Factor Estimates
B. Dial Up Factor Estimates
C. Comparison of WCS Original Model to Sample Based Estimates
D. Dial-Up Mass at Recommended Values Compared to Sample Based Mass Estimates
E. Sludge Batch 3 Estimates

Attachment A. Sample Data Used for Dial-Up Factor Estimates

Tank Sampled	Application	Sample Date (if known)	Sample Type (if known)	Sample Identification	Sample Reference	Al	Fe	Mn	Ni	Na
2	Use for Tk 2 and 3	Feb-66		Tank 2 Waste Removal (2/66)	DPSP-67-1-12 DPST-73-222	**2.19**	**17.31**	**17.31**	**0.5**	
5	Use for Tk 5	Oct-74	3 @ 3-liter	DP-1399 Tk 5 Composite	DP-1399	1.50	27.5	**10.8**	5.1	6.10
5	Use for Tk 5	Aug-75	Combined 3-liter	DP-1441 Tk 5 Composite	DP-1441	**1.57**	**28.9**	5.83	**6.34**	
4	Use for Tk 4 and 6			Fowler 4B, N-3381 Eibling	CBU-PIT-2006-38		**33.55**	1.32	5.91	2.74
6	Use for Tk 4 and 6.	Sep-75	Combined 3-liter	DP-1441 Tk 4/6 Composite	DP-1441	**2.28**	32.77	**1.99**	**6.29**	
9	Use for Tk 9 and 10	Jul-66		Tank 9 Waste Removal (7/66)	DPST-80-409	2.40	**14.6**	**9.6**	0.5	19.20
10	Use for Tk 9 and 10	Feb-67		Fowler 10A	DPST-80-409	**3.50**			**1.7**	0.40
12	Use for Tk 12	Sep-75	Combined 3-liter	DP-1441 Tk 12 Composite	DP-1441	**30.16**	**4.49**	1.69	0.46	1.03
12	Use for Tk 12	Aug-84	25-liter	Tk 12- 25 liter - Aug 84	Hamm, Bk#4, p. 158, 172	22.00	3.2			
12	Use for Tk 12	Aug-84	25-liter	Tk 12- 25 liter - Aug 84	Hamm, Bk#4, p. 158, 173	22.10	3.15			
12	Use for Tk 12	Aug-84	25-liter	Tk 12- 25 liter - Aug 84	Hamm, Bk#4, p. 158, 174	**21.70**	3.18	**1.86**		
12	Use for Tk 12	Sep-84	25-liter	Tk 12- 25 liter - Sept 84	Hamm, Bk#4, p. 159, 175	24.30	3.24	1.71		
12	Use for Tk 12	Sep-84	25-liter	Tk 12- 25 liter - Sept 84	Hamm, Bk#4, p. 159, 176	22.60	2.77	1.55		
12	Use for Tk 12	Sep-84	25-liter	Tk 12- 25 liter - Sept 84	Hamm, Bk#4, p. 159, 177	24.40	3.02	1.66		
12	Use for Tk 12	Aug-84	25-liter	Tk 12- 25 liter - Aug 84	Hamm, Bk#4, p. 158, 178		3.95	1.64	0.136	10.70
12	Use for Tk 12	Aug-84	25-liter	Tk 12- 25 liter - Aug 84	Hamm, Bk#4, p. 158, 179		4.43	1.75	**0.458**	8.71
12	Use for Tk 12	Aug-84	25-liter	Tk 12- 25 liter - Aug 84	Hamm, Bk#4, p. 158, 179		3.66	1.62	0.238	9.66
12	Use for Tk 12	Sep-84	25-liter	Tk 12- 25 liter - Sept 84	Hamm, Bk#4, p. 159, 180		3.72	1.71	**0.113**	10.50
12	Use for Tk 12	Sep-84	25-liter	Tk 12- 25 liter - Sept 84	Hamm, Bk#4, p. 159, 182		3.01	**1.49**	0.223	8.05
12	Use for Tk 12	Sep-84	25-liter	Tk 12- 25 liter - Sept 84	Hamm, Bk#4, p. 159, 183		**2.5**	1.65	0.258	0.48
13	Use for Tk 13	Aug-74	4 @ 3-liters	DP-1399 Tk 13 Composite	DP-1399	7.10	**27.9**	**8.8**	**0.5**	3.10
13	Use for Tk 13	Jul-75	Combined 3-liter	DP-1441 Tk 13 Composite	DP-1441	**9.22**	27.1	8.3	0.48	2.73
15	Use for Tk 15	Oct-74	3 @ 3-liters	DP-1399 Tk 15 Composite	DP-1399	**33.50**	**3.1**	2.3	0.51	1.20
15	Use for Tk 15			Fowler 15E, N-3381 Eibling	CBU-PIT-2006-38	25.81	29.5	2.62	**0.17**	3.42
15	Use for Tk 15			Fowler 15D, N-3234 Eibling	CBU-PIT-2006-38	3.99	6.07	0.8		1.80
15	Use for Tk 15	Aug-75	Combined 3-liter	DP-1441 Tk 15 Composite	DP-1441	**19.67**	5.5	**2.57**	**0.77**	2.57
15	Use for Tk 15		25-liter	Tk 15, Bottom 36 inches	DPST-80-361	20.50	**8**	**0.8**		1.60
18	Use for Tk 17 and 18			Fowler 18A	CBU-PIT-2006-38	**6.30**	**45.5**	**3.6**	**0.62**	5.08

Values in **BOLD** were selected for use in 'dial-up' factor estimates
Units are weight percent of washed, dried insoluble solids.

Attachment B. Dial-Up Factor Estimates

WASTE TYPE	For	TANK	Basis Volume of Settled Sludge (gal)	Basis (Settled Sludge/ Centrifuged sludge)	Basis (Kg solids per Liter centrifuged sludge)	Element Concentration Basis (wt%)	Element Estimated Mass (kg)	WCS Sludge 1.5 Original Model Addition to Tank Compound Basis	Gravimetric Factor	WCS Sludge 1.5 Original Model Addition to Tank Basis	Ratio
Pre-May 61 Purex LHW	Al	No data							0.329		
Pre-May 61 Purex HHW	Al	Tank 10H	67,000	2	0.6	3.5	2,663	1390	0.329	457	5.8
Pre-May 61 Purex HHW	Al	Tank 10H - Ref Comp	67,000	2	0.6	2.1	1,598	1390	0.329	457	3.5
HM HHW	Al	Tank 12H	257,000	2	0.6	30.16	88,014	79,972	0.329	26,311	3.3
HM HHW	Al	Tank 12H	257,000	2	0.6	21.7	63,326	79,972	0.329	26,311	2.4
HM HHW	Al	Tank 12H - Ref Comp	257,000	2	0.6	22.1	64,493	79,972	0.329	26,311	2.5
HM LHW	Al	Tank 13H	252,000	2	0.6	9.22	26,383	32,450	0.329	10,676	2.5
HM LHW	Al	Tank 13H - Ref Comp	252,000	2	0.6	6.8	19,458	32,450	0.329	10,676	1.8
HM HHW	Al	Tank 15H	323,000	2	0.6	19.7	72,253	90,820	0.329	29,880	2.4
HM HHW	Al	Tank 15H	323,000	2	0.6	33.5	122,867	90,820	0.329	29,880	4.1
HM HHW	Al	Tank 15H - Ref Comp	323,000	2	0.6	22.1	81,055	90,820	0.329	29,880	2.7
Post-May 61 Purex LHW	Al	Tank 17F	378,000	2	0.6	6.3	27,041	77,193	0.329	25,396	1.1
Post-May 61 Purex LHW	Al	Tank 17F - Ref Comp	378,000	2	0.6	4.6	19,744	77,193	0.329	25,396	0.8
Pre-May 61 Purex HHW	Al	Tank 2F	49,000	2	0.6	2.2	1,224	676	0.329	222	5.5
Pre-May 61 Purex HHW	Al	Tank 2F - Ref Comp	49,000	2	0.6	2.1	1,168	676	0.329	222	5.3
Pre-May 61 Purex HHW	Al	Tank 3F	78,000	2	0.6	2.2	1,949	1,636	0.329	538	3.6
Pre-May 61 Purex HHW	Al	Tank 3F - Ref Comp	78,000	2	0.6	2.1	1,860	1,636	0.329	538	3.5
Post-May 61 Purex HHW	Al	Tank 4F	127,000	2	0.6	2.28	3,288	7,007	0.329	2,305	1.4
Post-May 61 Purex HHW	Al	Tank 4F - Ref Comp	127,000	2	0.6	2.1	3,028	7,007	0.329	2,305	1.3
Post-May 61 Purex HHW	Al	Tank 5F	41,000	2	0.6	1.57	731	3,525	0.329	1,160	0.6
Post-May 61 Purex HHW	Al	Tank 5F - Ref Comp	41,000	2	0.6	2.1	978	3,525	0.329	1,160	0.8
Post-May 61 Purex HHW	Al	Tank 6F	25,000	2	0.6	2.28	647	6,592	0.329	2,169	0.3
Post-May 61 Purex HHW	Al	Tank 6F - Ref Comp	25,000	2	0.6	2.1	596	6,592	0.329	2,169	0.3
Pre-May 61 Purex HHW	Al	Tank 9H	46,000	2	0.6	3.5	1,828	642	0.329	211	8.7
Pre-May 61 Purex HHW	Al	Tank 9H - Ref Comp	46,000	2	0.6	2.1	1,097	642	0.329	211	5.2
Pre-May 61 Purex LHW	Fe	No data							0.522	-	
Pre-May 61 Purex HHW	Fe	Tank 10H	67,000	2	0.6	14.6	11,107	9,707	0.522	5,067	2.2
Pre-May 61 Purex HHW	Fe	Tank 10H - Ref Comp	67,000	2	0.6	25.4	19,324	9,707	0.522	5,067	3.8
HM HHW	Fe	Tank 12H	257,000	2	0.6	4.49	13,103	31,526	0.522	16,457	0.8
HM HHW	Fe	Tank 12H	257,000	2	0.6	2.5	7,296	31,526	0.522	16,457	0.4

WASTE TYPE	For	TANK	Basis Volume of Settled Sludge (gal)	Basis (Settled Sludge/ Centrifuged sludge)	Basis (Kg solids per Liter centrifuged sludge)	Element Concentration Basis (wt%)	Element Estimated Mass (kg)	WCS Sludge 1.5 Original Model Addition to Tank Compound Basis	Gravimetric Factor	WCS Sludge 1.5 Original Model Addition to Tank Basis	Ratio
HM HHW	Fe	Tank 12H - Ref Comp	257,000	2	0.6	5.3	15,467	31,526	0.522	16,457	0.9
HM LHW	Fe	Tank 13H	252,000	2	0.6	27.9	79,835	168,171	0.522	87,785	0.9
HM LHW	Fe	Tank 13H - Ref Comp	252,000	2	0.6	24	68,675	168,171	0.522	87,785	0.8
HM HHW	Fe	Tank 15H	323,000	2	0.6	8	29,341	27,671	0.522	14,444	2.0
HM HHW	Fe	Tank 15H	323,000	2	0.6	3.1	11,370	27,671	0.522	14,444	0.8
HM HHW	Fe	Tank 15H - Ref Comp	323,000	2	0.6	5.3	19,439	27,671	0.522	14,444	1.3
Post-May 61 Purex LHW	Fe	Tank 17F	378,000	2	0.6	45.5	195,295	229,491	0.522	119,794	1.6
Post-May 61 Purex LHW	Fe	Tank 17F - Ref Comp	378,000	2	0.6	25.1	107,734	229,491	0.522	119,794	0.9
Pre-May 61 Purex HHW	Fe	Tank 2F	49,000	2	0.6	17.3	9,626	5,933	0.522	3,097	3.1
Pre-May 61 Purex HHW	Fe	Tank 2F - Ref Comp	49,000	2	0.6	25.4	14,132	5,933	0.522	3,097	4.6
Pre-May 61 Purex HHW	Fe	Tank 3F	78,000	2	0.6	17.3	15,322	13,136	0.522	6,857	2.2
Pre-May 61 Purex HHW	Fe	Tank 3F - Ref Comp	78,000	2	0.6	25.4	22,497	13,136	0.522	6,857	3.3
Post-May 61 Purex HHW	Fe	Tank 4F	127,000	2	0.6	33.6	48,454	21,302	0.522	11,120	4.4
Post-May 61 Purex HHW	Fe	Tank 4F - Ref Comp	127,000	2	0.6	25.4	36,629	21,302	0.522	11,120	3.3
Post-May 61 Purex HHW	Fe	Tank 5F	41,000	2	0.6	28.9	13,455	24,202	0.522	12,633	1.1
Post-May 61 Purex HHW	Fe	Tank 5F - Ref Comp	41,000	2	0.6	25.4	11,825	24,202	0.522	12,633	0.9
Post-May 61 Purex HHW	Fe	Tank 6F	25,000	2	0.6	33.6	9,538	10,086	0.522	5,265	1.8
Post-May 61 Purex HHW	Fe	Tank 6F - Ref Comp	25,000	2	0.6	25.4	7,210	10,086	0.522	5,265	1.4
Pre-May 61 Purex HHW	Fe	Tank 9H	46,000	2	0.6	14.6	7,626	5,633	0.522	2,940	2.6
Pre-May 61 Purex HHW	Fe	Tank 9H - Ref Comp	46,000	2	0.6	25.4	13,267	5,633	0.522	2,940	4.5
Pre-May 61 Purex HHW	Mn	Tank 10H	67,000	2	0.6	9.6	7,304	11,948	0.632	7,551	1.0
Pre-May 61 Purex HHW	Mn	Tank 10H - Ref Comp	67,000	2	0.6	7.7	5,858	11,948	0.632	7,551	0.8
HM HHW	Mn	Tank 12H	257,000	2	0.6	1.86	5,428	23,077	0.632	14,585	0.4
HM HHW	Mn	Tank 12H	257,000	2	0.6	1.49	4,348	23,077	0.632	14,585	0.3
HM HHW	Mn	Tank 12H - Ref Comp	257,000	2	0.6	1.49	4,348	23,077	0.632	14,585	0.3
HM LHW	Mn	Tank 13H	252,000	2	0.6	8.8	25,181	25,809	0.632	16,311	1.5
HM LHW	Mn	Tank 13H - Ref Comp	252,000	2	0.6	4.5	12,877	25,809	0.632	16,311	0.8
HM HHW	Mn	Tank 15H	323,000	2	0.6	0.8	2,934	6,572	0.632	4,154	0.7
HM HHW	Mn	Tank 15H	323,000	2	0.6	2.57	9,426	6,572	0.632	4,154	2.3
HM HHW	Mn	Tank 15H - Ref Comp	323,000	2	0.6	1.6	5,868	6,572	0.632	4,154	1.4

WASTE TYPE	For	TANK	Basis Volume of Settled Sludge (gal)	Basis (Settled Sludge/ Centrifuged sludge)	Basis (Kg solids per Liter centrifuged sludge)	Element Concentration Basis (wt%)	Element Estimated Mass (kg)	WCS Sludge 1.5 Original Model Addition to Tank Compound Basis	Gravimetric Factor	WCS Sludge 1.5 Original Model Addition to Tank Basis	Ratio
Post-May 61 Purex LHW	Mn	Tank 17F	378,000	2	0.6	3.6	15,452	8,875	0.632	5,609	2.8
Post-May 61 Purex LHW	Mn	Tank 17F - Ref Comp	378,000	2	0.6	2.7	11,589	8,875	0.632	5,609	2.1
Pre-May 61 Purex HHW	Mn	Tank 2F	49,000	2	0.6	17.3	9,626	4,897	0.632	3,095	3.1
Pre-May 61 Purex HHW	Mn	Tank 2F - Ref Comp	49,000	2	0.6	7.7	4,284	4,897	0.632	3,095	1.4
Pre-May 61 Purex HHW	Mn	Tank 3F	78,000	2	0.6	17.3	15,322	12,976	0.632	8,201	1.9
Pre-May 61 Purex HHW	Mn	Tank 3F - Ref Comp	78,000	2	0.6	7.7	6,820	12,976	0.632	8,201	0.8
Post-May 61 Purex HHW	Mn	Tank 4F	127,000	2	0.6	1.99	2,870	6,492	0.632	4,103	0.7
Post-May 61 Purex HHW	Mn	Tank 4F - Ref Comp	127,000	2	0.6	7.7	11,104	6,492	0.632	4,103	2.7
Post-May 61 Purex HHW	Mn	Tank 5F	41,000	2	0.6	10.8	5,028	5,455	0.632	3,448	1.5
Post-May 61 Purex HHW	Mn	Tank 5F - Ref Comp	41,000	2	0.6	7.7	3,585	5,455	0.632	3,448	1.0
Post-May 61 Purex HHW	Mn	Tank 6F	25,000	2	0.6	2	568	2,381	0.632	1,505	0.4
Post-May 61 Purex HHW	Mn	Tank 6F - Ref Comp	25,000	2	0.6	7.7	2,186	2,381	0.632	1,505	1.5
Pre-May 61 Purex HHW	Mn	Tank 9H	46,000	2	0.6	9.6	5,014	4,492	0.632	2,839	1.8
Pre-May 61 Purex HHW	Mn	Tank 9H - Ref Comp	46,000	2	0.6	7.7	4,022	4,492	0.632	2,839	1.4
Pre-May 61 Purex HHW	Ni	Tank 10H	67,000	2	0.6	1.7	1,293	2,162	0.633	1,369	0.9
Pre-May 61 Purex HHW	Ni	Tank 10H - Ref Comp	67,000	2	0.6	3.7	2,815	2,162	0.633	1,369	2.1
HM HHW	Ni	Tank 12H	257,000	2	0.6	0.46	1,342	4,028	0.633	2,550	0.5
HM HHW	Ni	Tank 12H	257,000	2	0.6	0.113	330	4,028	0.633	2,550	0.1
HM HHW	Ni	Tank 12H - Ref Comp	257,000	2	0.6	0.6	1,751	4,028	0.633	2,550	0.7
HM LHW	Ni	Tank 13H	252,000	2	0.6	0.5	1,431	4,572	0.633	2,894	0.5
HM LHW	Ni	Tank 13H - Ref Comp	252,000	2	0.6	0.4	1,145	4,572	0.633	2,894	0.4
HM HHW	Ni	Tank 15H - Ref Comp	323,000	2	0.6	0.6	2,201	39	0.633	25	89.1
HM HHW	Ni	Tank 15H	323,000	2	0.6	0.17	624	39	0.633	25	25.3
HM HHW	Ni	Tank 15H	323,000	2	0.6	0.77	2,824	39	0.633	25	114.4
Post-May 61 Purex LHW	Ni	Tank 17F	378,000	2	0.6	0.62	2,661	-	0.633	-	
Post-May 61 Purex LHW	Ni	Tank 17F - Ref Comp	378,000	2	0.6	2.2	9,443	-	0.633	-	
Pre-May 61 Purex HHW	Ni	Tank 2F	49,000	2	0.6	0.5	278	1,051	0.633	665	0.4
Pre-May 61 Purex HHW	Ni	Tank 2F - Ref Comp	49,000	2	0.6	3.7	2,059	1,051	0.633	665	3.1
Pre-May 61 Purex HHW	Ni	Tank 3F	78,000	2	0.6	0.5	443	2,545	0.633	1,611	0.3
Pre-May 61 Purex HHW	Ni	Tank 3F - Ref Comp	78,000	2	0.6	3.7	3,277	2,545	0.633	1,611	2.0

Attachment B. Dial-Up Factor Estimates

WASTE TYPE	For	TANK	Basis Volume of Settled Sludge (gal)	Basis (Settled Sludge/ Centrifuged sludge)	Basis (Kg solids per Liter centrifuged sludge)	Element Concentration Basis (wt%)	Element Estimated Mass (kg)	WCS Sludge 1.5 Original Model Addition to Tank Compound Basis	Gravimetric Factor	WCS Sludge 1.5 Original Model Addition to Tank Basis	Ratio
Post-May 61 Purex HHW	Ni	Tank 4F	127,000	2	0.6	6.3	9,085	10,899	0.633	6,899	1.3
Post-May 61 Purex HHW	Ni	Tank 4F - Ref Comp	127,000	2	0.6	3.7	5,336	10,899	0.633	6,899	0.8
Post-May 61 Purex HHW	Ni	Tank 5F	41,000	2	0.6	6.34	2,952	5,484	0.633	3,471	0.9
Post-May 61 Purex HHW	Ni	Tank 5F - Ref Comp	41,000	2	0.6	3.7	1,723	5,484	0.633	3,471	0.5
Post-May 61 Purex HHW	Ni	Tank 6F	25,000	2	0.6	6.3	1,788	7,140	0.633	4,520	0.4
Post-May 61 Purex HHW	Ni	Tank 6F - Ref Comp	25,000	2	0.6	3.7	1,050	7,140	0.633	4,520	0.2
Pre-May 61 Purex HHW	Ni	Tank 9H	46,000	2	0.6	1.7	888	998	0.633	632	1.4
Pre-May 61 Purex HHW	Ni	Tank 9H - Ref Comp	46,000	2	0.6	3.7	1,933	998	0.633	632	3.1

Attachment C. Comparison of WCS Original Model to Sample Based Estimate

	Al (kg)	Fe (kg)	Mn (kg)	Ni (kg)
Start SB1A WCS	14,513	63,159	2,648	-
Start SB1A Samples	27,919	105,906	11,078	1,269
Sent SB1A WCS	10,374	45,145	1,893	-
Sent SB1A Samples	20,292	76,973	8,051	922
Heel SB1A WCS	4,139	18,014	755	-
Heel SB1A Samples	7,627	28,933	3,026	347
Input SB1A WCS	14,513	63,159	2,648	-
Input SB1A Samples	27,919	105,906	11,078	1,269
Start SB1B WCS	**22,927**	**60,068**	**3,607**	**7**
Start SB1B Samples	**39,258**	**110,188**	**16,913**	**1,748**
Sent SB1B WCS	**20,207**	**52,940**	**3,179**	**6**
Sent SB1B Samples	**36,439**	**102,275**	**15,698**	**1,622**
Heel SB1B WCS	**2,720**	**7,127**	**428**	**1**
Heel SB1B Samples	**2,819**	**7,913**	**1,215**	**126**
Input SB1B WCS	**18,788**	**42,054**	**2,851**	**7**
Input SB1B Samples	**31,630**	**81,255**	**13,886**	**1,401**
Start SB2 WCS	24,108	85,227	6,115	4,183
Start SB2 Samples	30,093	123,083	16,741	6,206
Sent SB2 WCS	10,574	37,381	2,682	1,835
Sent SB2 Samples	16,021	65,528	8,913	3,304
Heel SB2 WCS	13,534	47,847	3,433	2,348
Heel SB2 Samples	14,072	57,554	7,828	2,902
Input SB2 WCS	24,108	85,227	6,115	4,183
Input SB2 Samples	30,093	123,083	16,741	6,206
Start SB3 WCS	**46,054**	**143,262**	**22,434**	**6,696**
Start SB3 Samples	**39,319**	**125,454**	**27,233**	**7,520**
Sent SB3 WCS	**4,075**	**12,734**	**1,949**	**597**
Sent SB3 Samples	**6,691**	**21,349**	**4,634**	**1,280**
Heel SB3 WCS	**41,979**	**130,529**	**20,485**	**6,099**
Heel SB3 Samples	**32,628**	**104,105**	**22,598**	**6,240**
Input SB3 WCS	**32,520**	**95,416**	**19,001**	**4,348**
Input SB3 Samples	**25,248**	**67,900**	**19,404**	**4,618**

Attachment C. Comparison of WCS Original Model to Sample Based Estimate

	Al (kg)	Fe (kg)	Mn (kg)	Ni (kg)
WCS Sum of Input (SB1A, SB1B, SB2)	57,409	190,440	11,614	4,190
Sample Sum of Input	89,642	310,243	41,705	8,876
Start SB4 WCS	**18,666**	**19,715**	**3,147**	**503**
Start SB4 Samples	**70,381**	**34,956**	**8,325**	**3,054**

Attachment D. Dial-Up Mass at Recommended Values Compared to Sample Based Mass Estimate

	Al (kg)	Fe (kg)	Mn (kg)	Ni (kg)
Start SB1A WCS	14,902	69,729	5,291	-
Start SB1A Samples	27,919	105,906	11,078	1,269
Sent SB1A WCS	10,652	49,842	3,782	-
Sent SB1A Samples	20,292	76,973	8,051	922
Heel SB1A WCS	4,250	19,888	1,509	-
Heel SB1A Samples	7,627	28,933	3,026	347
Input SB1A WCS	14,902	69,729	5,291	-
Input SB1A Samples	27,919	105,906	11,078	1,269
Start SB1B WCS	**41,604**	**77,553**	**5,492**	**7**
Start SB1B Samples	**39,258**	**110,188**	**16,913**	**1,748**
Sent SB1B WCS	**36,668**	**68,351**	**4,840**	**6**
Sent SB1B Samples	**36,439**	**102,275**	**15,698**	**1,622**
Heel SB1B WCS	**4,937**	**9,202**	**652**	**1**
Heel SB1B Samples	**2,819**	**7,913**	**1,215**	**126**
Input SB1B WCS	**37,354**	**57,666**	**3,983**	**7**
Input SB1B Samples	**31,630**	**81,255**	**13,886**	**1,401**
Start SB2 WCS	26,131	105,122	12,121	4,183
Start SB2 Samples	30,093	123,083	16,741	6,206
Sent SB2 WCS	11,461	46,107	5,316	1,835
Sent SB2 Samples	16,021	65,528	8,913	3,304
Heel SB2 WCS	14,670	59,016	6,805	2,348
Heel SB2 Samples	14,072	57,554	7,828	2,902
Input SB2 WCS	26,131	105,122	12,121	4,183
Input SB2 Samples	30,093	123,083	16,741	6,206
Start SB3 WCS	**50,851**	**169,464**	**44,614**	**6,696**
Start SB3 Samples	**39,319**	**125,454**	**27,233**	**7,520**
Sent SB3 WCS	**4,497**	**15,094**	**3,876**	**597**
Sent SB3 Samples	**6,691**	**21,349**	**4,634**	**1,280**
Heel SB3 WCS	**46,354**	**154,370**	**40,738**	**6,099**
Heel SB3 Samples	**32,628**	**104,105**	**22,598**	**6,240**
Input SB3 WCS	**36,181**	**110,448**	**37,809**	**4,348**
Input SB3 Samples	**25,248**	**67,900**	**19,404**	**4,618**

Attachment D. Dial-Up Mass at Recommended Values Compared to Sample Based Mass Estimate

	Al (kg)	Fe (kg)	Mn (kg)	Ni (kg)
WCS Sum of Input (SB1A, SB1B, SB2)	78,387	232,517	21,394	4,190
Sample Sum of Input	89,642	310,243	41,705	8,876
Start SB4 WCS	**41,777**	**31,475**	**4,199**	**503**
Start SB4 Samples	**70,381**	**34,956**	**8,325**	**3,054**

ATTACHMENT E. SLUDGE BATCH 3 ESTIMATE

The Sludge Batch 3 Estimate is more complicated than the other batches because there is not a single sample that is a good representation of the batch composition.

The batch was largely made up in Tank 51H and then transferred to Tank 40H. This transfer was made in two steps and is on top of the large heel that remained in Tank 40H. Tank 40 was not sampled, however, until almost 100,000 kg of calcine solids had been transferred to DWPF. In addition, there were a lot of transfers of unusual streams (Plutonium and Neptunium) into the batch and there were various additions of inhibitors and bearing water.

The (shortened version) chronology was:

Event	Date
Complete transfers from Tank 7 to tank 51	6/25/03
Run slurry pumps in Tank 51H for four hours and then pull sample **(Tk 51E)**	6/30/03
Run slurry pumps in Tk 51	7/11/03
Decant Tank 51 to 220 inches	7/18/03 through 7/23/03
Tank 51 Pu receipts	10/24/03 through 11/7/03
Tank 51 mixing	11/12/03
Tank 51 decant (supernate) and inhibitor additions	12/8/03 through 12/19/03
Tank 51 mixing and three 100 ml samples taken **(Tk 51F)** (final level is 131.5 inches)	12/21/03
Inhibitor addition to Tank 51	3/3/04 through 3/5/04
Transfer 306,000 gallons from Tank 51 to Tank 40	3/10/04 through 3/14/04
Np stream transfer to Tank 40	3/15/04 through 3/22/04
Tank 40 mixing and two 100 ml samples taken **(Tk 40D)**	3/22/04 through 3/23/04
Transfers from Tk 40 (SB3) to DWPF	Starting 3/23/04
Np stream transfer to Tank 40	5/5/04 through 6/4/04
Transfer 132,000 gallons from Tank 51 to Tank 40 (final Tank 51 tank level is 6.4 inches)	6/12/04 through 6/14/04
Sample Tank 40 (3 liter sample) **(Tk 40E)**	November 13, 2004

This complicated progression of transfers and samples makes the definition of a single composition of the batch very difficult. Two different approaches have been taken, with different outcomes.

Application of Approach A

Designate the Tk 40E sample as the one that will be used to characterize the batch and apply this composition to a theoretical 'start of batch' obtained by summing the mass estimate from the date the sample was taken plus the mass estimate of what has been sent to DWPF up to that date.

As of 11/13/04, the tank level was 222.9 inches, the specific gravity of the slurry was 1.15, and the total solids are 18.66%. The total solids are therefore 635,466 kg.

And, as of 11/13/04 approximately 99,717 kg of calcine have been fed to DWPF. The calcine factor is 0.766. Therefore, the total solids are 99,717/0.766 or 130,179 kg.

Summing these two, the total solids at the start of the batch are 635,466 kg plus 130,179 kg or 765,645 kg.

The sample results are applied to the start of the batch are as follows:

Element	Wt % of Total Solids	Mass (Start of batch)
Al	5.14	39,319
Fe	16.4	125,454
Mn	3.56	27,233
Ni	0.983	7,520

The amounts that are in the heel from the previous batch are shown below. By difference, the amount that was input into the tank was as follows:

Element	SB3 Start (1)	SB2 Heel (2)	Mass (Input) (1-2)
Al	39,319	14,072	25,248
Fe	125,454	57,554	67,900
Mn	27,233	7,828	19,404
Ni	7,520	2,902	4,618

Application of Approach B

Designate the Tk 51F sample as the one that will be used to characterize the input to the batch and apply this composition to a theoretical input based on the total difference in tank level in Tank 51 (from 131.5 inches to 6.4 inches).

The Tk 51F sample results were a specific gravity of 1.21 and a total solids of 25.9 wt%.

Applying this to the volume difference (131.5 inches – 6.4 inches), the total mass is 520,853 kg. Using the composition data, the mass of the input stream is as shown below.

Element	Wt % of Total Solids	Mass, Kg (Input)
Al	6.72	35,001
Fe	15.10	78,649
Mn	4.41	22,969
Ni	1.03	5,365

Difference

Using the two different points in the process, the theoretical amount of solids input to the batch are as follows (from above)

Element	Approach A Input, kg	Approach B Input, kg	Difference (B-A), kg
Al	25,248	35,001	9,753
Fe	67,900	78,649	10,749
Mn	19,404	22,969	3,565
Ni	4,618	5,365	747

Conclusion

Sludge Batch 3 does not have a single sample that can be used to characterize the final, assembled batch. Two different approaches have been applied. The results are about 10,000 kg different for both iron and aluminum.